



## Tetra Tech EM Inc.

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N00236.001614  
ALAMEDA POINT  
SSIC NO. 5090.3

April 16, 1999

Mr. George Kikugawa  
Remedial Project Manager  
Engineering Field Activity West  
Naval Facilities Engineering Command  
900 Commodore Drive, Building 208  
San Bruno, California 94066-2402

**Subject: Transmittal of Response to Survey and Sampling Approach Proposed by DTSC  
Installation Restoration Sites 5 and 10  
Alameda Point, Alameda, California  
CLEAN II Contract No. N62474-94-D-7609, Contract Task Order No. 147 and 239**

Dear Mr. Kikugawa:

As requested by LCDR Vincent DeInnocentiis of the Radiological Affairs Support Office (RASO), Tetra Tech EM Inc. (TtEMI) is providing in response to comment format this alternative survey approach and sampling for the above-referenced work. This survey and sampling approach is based on and is a response to a proposed survey and sampling approach provided by DTSC. TtEMI has discussed this response with RASO.

This survey and sampling approach substantially conforms to the survey and sampling approach proposed by DTSC (for the work areas which have been impacted by pipe repairs), and to the original workplan (for areas judged to be unimpacted above the pipeline). This survey and sampling approach is different from DTSC's in that it relies on less sampling and more direct radiation surveys.

If you have any questions, please call me at (415) 222-8228.

Sincerely,

Edward Ho  
Project Manager

Enclosure

cc: George Kikugawa, Navy RPM  
LCDR Vincent DeInnocentiis, RASO  
David Horton, IOC  
Conrad Sherman, TtEMI  
File

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**RESPONSE TO THE  
SURVEY AND SAMPLING PLAN FOR REMOVAL OF CONTAMINATED  
STORM DRAIN BETWEEN MANWAYS 5F AND 6F, ALAMEDA POINT**

This document presents the U.S. Department of the Navy's (Navy) responses to the survey and sampling plan for removal of contaminated storm drain sections between manways 5F and 6F, Alameda Point, proposed by the Department of Toxic Substances Control (DTSC) in conjunction with the Department of Health Services (DHS), in a letter dated February 11, 1999. That sampling plan applied to sections where the Navy had not replaced pipe as of April 9, 1999 and to sections where surveying had not been previously completed (F1 to F10).

**RESPONSE TO COMMENTS FROM THE DTSC**

**General Comments**

1. **Comment:** Any information that would indicate potential contaminated soil beyond the proposed areas to be surveyed or sampled should be provided at this time and corrections made to the plan.

**Response:** The Navy will classify the 6F to 5F run into two categories based on the categories described in the EPA multiagency radiation site survey and assessment guidance manual (MARSSIM). Those categories are:

- Impacted Class 1—sections impacted by a breach of pipe integrity, with soil concentrations in excess of 5 pCi/g;
- Impacted Class 3—sections where there is no evidence of a breach of integrity of the storm drain pipeline or soil contamination in excess of 5 pCi/g.

The Impacted Class 1 and 3 sections will be surveyed and sampled as outlined below. The information contained in this response will be incorporated into the revised work plan.

**RESPONSE TO COMMENTS FROM THE DHS**

**General Comments**

1. **Comment:** The following sampling plan is recommended to demonstrate that the goals of the TWD/RAP are met for the storm drain removal project between Manway 5F and 6F. If this sampling plan is not agreed to, then DHS recommends that surveys and sampling not proceed until one developed that is acceptable to all.

It should also be noted that this proposed plan is based on the current knowledge of DHS personnel as to the potential extent of contamination given the history of repair of this storm drain section. Any information that would lead to potential contaminated soil beyond the proposed areas to be surveyed or sampled should be provided at this time and corrections made to the plan.

**Response:** The Navy is proposing an alternate plan as outlined in the responses to comments two through four below. This plan provides a high degree of assurance that elevated activity will not go undetected.

The Navy is proposing to place more reliance on the field screening analytical data developed by the remediation contractor. A field screening detection system operated by the remediation contractor, New World Technologies (NWT), will be utilized for initial assay of the soil samples. This system will be qualified by counting DHS performance samples and blind quality assurance samples that are based on known soil activity as determined by the independent lab. NWT is a California-licensed remediation contractor, and its analytical results have been acceptable to the state for other projects. In addition, NWT's results will be compared with the independent laboratory results for split and duplicate count samples.

**2. Comment: Sampling and surveys in the trench prior to clean pipe placement:**

**a. For every 100 feet of trench:**

Navy will survey based on its established 10-foot grids; the proposed frequencies are adjusted accordingly (divided by 10).

**b. 100% gamma scans of all exposed surfaces of the trench, including sidewalls. Surveys through standing water would not be acceptable.**

Navy will do this for the entire trench, including sidewalls.

**c. 30 soil samples shall be collected at the surface of the trench bottom at randomly selected locations.**

For Class 1 sections, Navy will collect 3 samples per grid on a random basis. NWT will analyze the samples on site. The highest will go to the independent lab for analysis. See section g of this comment for Class 3 areas.

**d. In addition, 10 boring samples shall be collected at 18" below the trench surface at randomly selected locations.**

For Class 1 sections, Navy will collect 1 sample per grid at 18" below the trench surface with a hand auger or from soil from the backhoe bucket. NWT will analyze samples onsite. See section g of this comment for Class 3 areas.

**e. Collect additional soil samples where the scan survey indicates 7,200 cpm (equivalent to 8  $\mu$ R/hr) above the lowest reading in each 20-foot section.**

Additional samples will be collected every 20 feet (2 grids) if the count rate exceeds 7,200 cpm above the lowest reading. NWT will analyze onsite. The highest will go to the independent lab. The Navy will lower the action level to 1,800 net cpm<sup>1</sup> for scanning through sheet piling, to assure that significant elevated areas can be reliably detected. Microshield™ calculations are included (Appendix A) to demonstrate the scan sensitivity achieved will be approximately 2.5 picocuries per gram (pCi/g) (Note: the review of these calculations should not affect the work schedule.)

f. The Navy proposes the following for Impacted Class 1 sections.

The Navy will perform gamma scan surveys of the trench bottom and trench sidewalls from the trench bottom up to the ground surface using the standard 2- inch scintillation detector. Microshield™ Version 5 has been used to confirm sensitivity of the detection system through the steel sheet pile side walls. Calculations are included in Appendix A. An investigation level of 1,800 net counts per minute and a scan minimum detectable concentration (MDC) of 2.5 picocuries per gram will be used for scanning through sheet piling. If the investigation level is exceeded, a soil sample will be collected at the depth of the highest location (6" to 1 foot on the other side of the shoring). This corresponds to detection of a small area of elevated contamination through the sheet piling.

An improved shoring system will be used to minimize water intrusion; however, some water intrusion may be unavoidable. Navy will notify DHS if water is greater than 4" depth.

g. The Navy proposes the following sampling for Impacted Class 3 sections:

In each Impacted Class 3 grid section, NWT will collect and analyze one sample every 10 feet. After remediation, the Navy (CLEAN contractor) will collect one additional sample every 20 feet, biased to the centerline of the old pipe, and one additional sample at the highest location exceeding the investigation level of 7,200 cpm for the trench bottom.

After the NWT analysis of samples from the Impacted Class 3 grid, the independent laboratory will analyze the highest sample from the NWT and Navy samples.

3. **Comment:** **Sampling and surveys in soil adjacent to the storm drain trench.**

a. For every 100 feet on both sides of the trench:

A three dimensional grid system shall be made of the soil adjacent to both sides of the trench to include all soil within 5 feet of the trench wall and 2

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<sup>1</sup> The investigation level and scan MDC will vary depending on site-specific background. The scan speed can be adjusted to maintain scan MDC no greater than 3 pCi/g.

feet deeper than trench bottom. Select 30 random locations varying both depth and horizontal location for sampling.

The Navy will collect 3 samples on each side per Class 1 impacted grid randomly over area and depth judged to be impacted (equal or greater than proposed above) using a geoprobe™ device. The trench sidewalls will not be sampled in Class 3 areas.

**b. Perform a 100% gamma scan survey on all soils within this area that may become exposed during the removal work. (This would mean performing a scan prior to backfilling any locations adjacent to the trench.)**

Navy will do this.

**c. Collect 30 surface soil samples below road coverings out to 10 feet on either side of the trench.**

The Navy has developed a scan MDC and action level for further investigation at 3.6 pCi/gram, at a net count rate increase of 1,170 cpm, using Microshield™ and the methods outlined in MARSSIM to calculate the effect of asphalt or concrete overburden (Refer to Appendix A for calculations). This work will be subject to DHS evaluation of the scan sensitivity calculations. Paved areas will be surveyed as noted below.

If the investigation level is exceeded, a soil sample will be collected below the road covering.

**d. Perform a 100% gamma scan survey of all areas within 20 feet of the trench.**

Class 1 areas will be surveyed out to 20 feet, Class 3 areas to 10 feet.

These surveys will be conducted using high precision (within 1-meter circular error probability) satellite positioning and automatic data recording. Detector response will be correlated to accurate exposure rate measurements using an HPI Model 1010 Tissue Equivalent Ionization Chamber.

**4. Comment: Laboratory Analysis:**

Soil sample analysis shall be at the Tetra Tech EM, Inc. approved laboratory. All quality assurance requirements are still required. Final sample results shall be reported in pCi/g dry weight using the 609 keV peak and when the radium daughters are in equilibrium,

Any piping connected to this section of storm drain should be surveyed and sampled as previously done for other laterals.

**Response:** Independent laboratory analysis will be performed by counting the photopeak at 186-kiloelectron volts (keV) produced by decay of radium-226. The independent laboratory has demonstrated the adequate sensitivity and specificity using the 186 keV line of radium-226 itself. (It is acknowledged that U-235 will increase the radium-226 result when assaying in this manner). The

laboratory will determine moisture content of each sample and correct the wet count result to dry weight. These methods were designed to meet the projects rapid analytical turnaround time requirements. As previously discussed between TtEMI and DHS, before relying on background data, the Navy will determine background by relying on daughter radiations in an equilibrium (30 day hold) sealed sample.

NWT will survey laterals as described in the "Radiation Survey and Field Sampling Work Plan, Naval Air Station, Alameda, California," dated December 1996. The detection sensitivity will be no greater than 15 nanocuries for a point source in lieu of the 100 nanocuries specified in the "Radiation Survey Statement of Work, Revised," dated August 20, 1996. No sampling is proposed for lateral lines.

## **APPENDIX A**

### **SCAN SENSITIVITY CALCULATIONS**

## APPENDIX A

### MICROSHIELD™ DESCRIPTION

The Microshield™ (MS) computer program can be used to calculate the radiation exposure rate (RER) from a variety of specific radiation source geometries (Grove Engineering 1996). The use of MS is endorsed by the U.S. Environmental Protection Agency (EPA) "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) (EPA 1997) for calculating scan detection limits. MS allows for a calculation to consider variation in the following conditions:

- Source type (line, plan, volume)
- Source geometry (slab, cylinder, annulus)
- Source composition (soil, water, air, concrete)
- Radiation shield material (asphalt, air, water, soil, concrete)
- Immersion medium (air, water)

MS allows the user to choose radiation dose receptor position by specifying the x, y, and z coordinates of the receptor.

In MARSSIM (EPA 1997), EPA determines the minimum detectable concentration (MDC) of radioactivity in soil that can be identified by scanning measurement using a scintillation-type radiation detector. MS determines the RER from a specific source size, activity, concentration, and detector spacing. From the RER, the MDC can then be calculated in accordance with the specified methodology.

This approach described in MARSSIM (EPA 1997) can be modified to consider the effect of a shielding layer over the impacted soil. This layer may be asphalt paving material, sheet piling shoring (iron), or soil layers. The examples used by EPA can also be modified for additional factors such as soil composition and soil moisture content. The set of standard factors used to model a specific condition are known as the "calculational basis."



The following calculational basis was used for this report:

Soil Composition	Sandy Loam Soil
Soil Moisture	29 percent
Effective Soil Bulk Density	1.24 (including moisture) grams per cubic centimeter (g/cm <sup>3</sup> )
Activity Concentration	5 picocuries per gram (pCi/g) of soil (dry)
Air Density	0.00122 gram per cubic meter

Additionally, an exposure rate to detector response factor of 760 counts per minute (cpm) per microrentgen per hour (for radium-226) is used in all calculations.

Each problem, defined as a shielding problem, may be investigated using MS by a single computation or by a series of computations. Each computation is referred to as a "case." To simulate a complex problem, the calculational results of several cases may be combined.

This appendix describes the way MS may be used to study the effect of interposing a layer of metal sheet piling between the soil and radiation detector on the radiation scan MDC.

#### **IMPACT OF SHEET PILE SHIELD ON SCAN MINIMUM DETECTABLE CONCENTRATION**

The scan MDC was calculated for unshielded soil using the methods described by EPA (1997) for the soil condition described in the following paragraph (refer to case file "S-PILE-6.MS5"). Next, the effect of a 1-centimeter (cm)-thick iron layer on the detector response was investigated using MS (refer to case file "S-PILE-7.MS5"). A 29 percent moisture content was used in all calculations for soil, as an approximation for the moist soil conditions at Site 5. The soil composition used is presented as Attachment 1 to this appendix. Attachment 2 provides the attenuation properties calculated and tabulated by MS for this material composition. The effective soil density for input to MS is 1.25 grams per cubic cm (g/cm<sup>3</sup>). This value is derived from soil having a dry bulk density of 1.6 g/cm<sup>3</sup>. The soil concentration corresponding to 5 picocuries per g (pCi/g) of radium-226 (on a dry weight basis) calculated from the weight percent based on moisture content is 4.25 pCi/cm<sup>3</sup> of radium-226 and 4.25 pCi/cm<sup>3</sup> of each series progeny. This is equal to  $4.25 \times 10^{-6}$  microcuries (μCi)/cm<sup>3</sup>, which was then

used for a source term in the required input unit dimensions of MS. Each MS run's output consists of a case summary sheet describing the geometry of the source and receptor, the input source term, and the output. In the output data, the last column (entitled "Exposure Rate mR/hr With Buildup") of the last row (entitled "TOTALS") is the total exposure rate with buildup, which is the desired value for use in the scan MDC calculation. Exposure rates in millirem per hour multiplied by 760,000 counts per minute per milliroentgen per hour are for radium-226. These conversions are calculated explicitly for other radionuclides using Table 6.3 of the "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions" (NUREG-1507) (Nuclear Regulatory Commission [NRC] 1998) from the energy group exposure rates provided in the MS output. MARSSIM (EPA 1997) and NUREG-1507 (NRC 1998) both explain the derivation of these response factors. The nominal detector response in counts per minute (cpm) is the sum over all the energy groups of the product of energy group exposure rates and the energy group response conversion factors.

The response of the detector is calculated over a small source 80 cm high, 80 cm wide, and 15 cm deep. The response is calculated for no shield (which corresponds to a scan for activity on the surface) and for a 1-cm iron layer, (corresponding to a layer of sheet pile). Table 1 summarizes MS output.

Relevant MS data such as material composition files are provided in Attachment 1. Attenuation properties such as buildup factor as a function of mean free path (MFP) are provided as Attachment 2. Other relevant MS data such as source activity files are provided as Attachment 3. MS run file names are listed, and corresponding output files are provided as Attachment 4.

#### **IMPACT OF ASPHALT LAYER ON SCAN MINIMUM DETECTABLE CONCENTRATION**

Similar calculations were performed for scan MDC for surfaces covered by asphalt. A 40 cm radius by 15 cm deep source was used, with a 10 cm asphalt cover. MS output is included for this case in Attachment 4 under run file name ASPH-1.MS5.

#### **CALCULATION OF SCAN MINIMUM DETECTABLE CONCENTRATION**

This section summarizes the approach used for calculation of MDCs for scan surveys following the methods of the MARSSIM (EPA 1997) and NUREG-1507 (NRC 1998). Scan MDCs are used to demonstrate the viability of using a field portable detection system such as a sodium iodide scintillation

detector to supplement or replace sampling techniques. For each case or condition of interest, the following process is used as outlined in MARSSIM and NUREG-1507.

- Determine the area factor acceptable for deriving the maximum concentration acceptable for a small area. (This area factor is determined as 1 in the present study at Alameda Point.)
- Establish the source size, concentration, and overlay or shielding for the case.
- Use MS<sup>TM</sup> or other shielding code to calculate the exposure rate at the receptor point.
- Calculate the scan MDC from the scan rate, source width, background exposure rate, and detector response factor.

A number of conditions were investigated in this manner. Each condition and results are summarized in the following text. Scan detection limit calculations are presented for each case in Table 2. Table 2 also includes an example based on the MARSSIM report for radium-226 for comparison of this method to the value used in MARSSIM (EPA 1997). The actual Excel<sup>TM</sup> spreadsheet used for scan MDC calculations is reproduced in Table 2. Terms are as defined in MARSSIM. In addition to the scan MDC, the gross and net detector response at 5 pCi/g is tabulated. The fixed MDC for a 1-minute count is also estimated.

### **Example**

The example used in MARSSIM (EPA 1997) consists of a dry soil volume of density 1.6 g/cm<sup>3</sup>. MARSSIM does not describe the soil composition or moisture content. The background cited in MARSSIM was used in the example calculation. The Navy has used a sandy loam soil and a moisture content of 29 percent by weight in these calculations. The calculated scan MDC of 2.65 pCi/g calculated compares favorably with the value for the scan MDC cited in MARSSIM of 2.8 pCi/g when using a 2-inch sodium iodide detector.

### **Shielded Sheet Pile**

The source size used in MARSSIM (EPA 1997) was used to calculate the scan MDC for the situation where a 1-cm steel layer shields the source. A lower background, typical of that experienced at Alameda Point, was used in this calculation. In this case, the scan MDC of 2.29 pCi/g did not exceed 5 pCi/g.

### **No Shielded Layer**

The source size used in MARSSIM (EPA 1997) was used to calculate the scan MDC for the situation where no steel layer shields the source. A lower background, typical of that experienced at Alameda Point, was used in this calculation. In this case also, the scan MDC of 1.42 pCi/g did not exceed 5 pCi/g.

### **Asphalt Shielded Soil Layer**

The technique used in MARSSIM (EPA 1997) was used to calculate the scan MDC for the situation where a 10 cm layer of asphalt shields the source. A lower background, typical of that experienced at Alameda Point, was used in this calculation. In this case also, the scan MDC of 3.66 pCi/g did not exceed 5 pCi/g.

### **Summary**

The calculation result is presented for each run in Table 1. The result of this calculation shows that the effect of shielding is slight and that in each case the scan MDC is below 5 pCi/g.

TABLE 1

**MICROSHIELD™ OUTPUT AND CALCULATED DETECTOR RESPONSE FOR SHIELDED  
(IRON) AND UNSHIELDED CASE**

Nuclide Series	Run File Name (*MS5 )	Exposure Rate mR/hr ( $\times 10^{-3}$ )	Net Response (counts per minute) <sup>a</sup>	Scan MDC (pCi/g)
<b>Iron Shield Layer (1 cm )</b>				
Radium-226 + D	S-PILE-7	2.32	1,870	2.29
<b>Gross Detector Response (Iron Shield) <sup>b</sup></b>				<b>= 6,430 cpm</b>
<b>No Shield Layer</b>				
Radium-226 + D	S-PILE-6	3.745	3,020	1.42
<b>Gross Detector Response (No Shield) <sup>b</sup></b>				<b>= 7,580 cpm</b>
<b>Asphalt Shield Layer</b>				
Radium-226 + D	ASPH-1	1.45	1,170	3.66
<b>Gross Detector Response (Asphalt Layer) <sup>b</sup></b>				<b>= 5,730 cpm</b>

**Note:**

- a Values are rounded.  
b Will vary with background.

Table 2  
CALCULATION OF SCAN MINIMUM DETECTION LIMITS FOR  
2-INCH-BY-2-INCH SODIUM IODIDE SCINTILLATION DETECTOR

Case Description		MARSSIM Example	Shielded Sheet pile	No Shield Layer	Asphalt Layer
Source Depth (cm)		15	15	15	15
surveyor efficiency		0.5	0.5	0.5	0.5
cpm/ $\mu$ R/hr		760	760	760	760
source width (cm)		58	80	80	80
scan speed (m/s)		0.5	0.5	0.5	0.5
background ( $\mu$ R/hr)		14	6	6	6
background cpm		10640	4560	4560	4560
dwell time		1.2	1.6	1.6	1.6
$b_1$ =		205.71	121.60	121.60	121.60
mdcr =		1023.76	570.66	570.66	570.66
mdcr-surveyor		1447.81	807.03	807.03	807.03
MDC (exposure)		1.91	1.06	1.06	1.06
Scan MDC	Microshield Basis	5	5	5	5
	Microshield ( $\mu$ R/hr)	3.60	2.32	3.74	1.45
	Scan MDC (pCi/g)	<b>2.65</b>	<b>2.29</b>	<b>1.42</b>	<b>3.66</b>
	$\mu$ R/hr per pCi/g	0.72	0.46	0.75	0.29
	pCi/g per $\mu$ R/hr	1.39	2.16	1.34	3.45
	net cpm at basis	<b>5212</b>	<b>1872</b>	<b>3018</b>	<b>1170</b>
	gross cpm at basis=	15852	6432	7578	5730
Fixed MDC	net cpm at MDC	1448	807	807	807
	Detection Level	11120	4874	4874	4874
	Net Detection ( $\mu$ R/hr)	0.63	0.41	0.41	0.41
	1 Minute MDC	<b>0.88</b>	<b>0.89</b>	<b>0.55</b>	<b>1.42</b>

## Table 2 Notes:

### Table 2 Equations

$$\begin{aligned} \text{MDCR} &= d \times \sqrt{b_i} \times (60/i) \\ \text{Scan MDC} &= \text{MDCR} / (\sqrt{b_i} \times \epsilon \times A_p \times (1/100\text{cm}^2)) \\ \text{MDCR}_{\text{surveyor}} &= \text{scan MDC} / \sqrt{b_i} \\ \text{MD}_R &= \text{MDCR}_{\text{surveyor}} / \text{cpm}/\mu\text{r}/\text{hr}(\text{detector}) \\ \text{Scan MDC}_{\text{direct}} &= \text{basis} \times (\text{MD}_R / \text{Microshield}^{\text{TM}} \text{ value}) \end{aligned}$$

$A_p$	Area of the probe (this is not used with the gamma scintillation detector and is set to 100)
cpm	Count per minute
$d$	A detectability index of 1.38 was used corresponding to a 5 percent chance of false negative error and a 25 percent chance of false positive error see MARSSIM (Table 6.5) (EPA 1997)
$\epsilon$	The probe efficiency
hr	Hour
$\mu\text{R}$	Micro Roentgen
MDC	Minimum detectable concentration
MDCR	Minimum detectable count rate
$\text{MD}_R$	The minimum detectable exposure rate
$b_i$	The average number of counts in a observation interval
$i$	The observation interval, see MARSSIM (EPA 1997)
$\sqrt{\phantom{x}}$	Square root

## REFERENCES

Grove Engineering, 1996. Microshield, Version 5, Users Manual. Rockville, Maryland.

Nuclear Regulatory Commission. 1998. Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. NUREG-1507. June.

U.S. Environmental Protection Agency. 1997. Multi-Agency Radiation Survey and Site Investigation Manual. NUREG-1575/EPA-402-R-97-016. December.



**ATTACHMENT 1**

**SOIL AND ASPHALT COMPOSITION**

## MicroShield v5.03 (5.03-00232)

Tetra Tech EM Inc.

Custom Material : sandy loam moist  
sandy loam with moisture content

Density : 1.25 g/cm<sup>3</sup>

Average Atomic Number : 11.36 (based on average elements Z)

Effective Atomic Number : 10.15 (for Buildup Factor Interpolation)

Effective Atomic Weight : 12.9

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
	28.926%	63.854%	1.262%	4.561%	1.011%	0.385%
Hydrogen	2					
Oxygen	1	2	3	3	1	2
Aluminum				2		
Silicon		1				
Potassium					2	
Titanium						1
Iron			2			

**MicroShield v5.03 (5.03-00232)****Tetra Tech EM Inc.****Custom Material : asphalt  
asphalt hydrocarbon and sio2****Density : 1.3 g/cm<sup>3</sup>****Average Atomic Number : 5.85 (based on average elements Z)****Effective Atomic Number : 6.08 (for Buildup Factor Interpolation)****Effective Atomic Weight : 11.7**

1  
100.000%

Hydrogen

2

Carbon

50

Oxygen

0.25

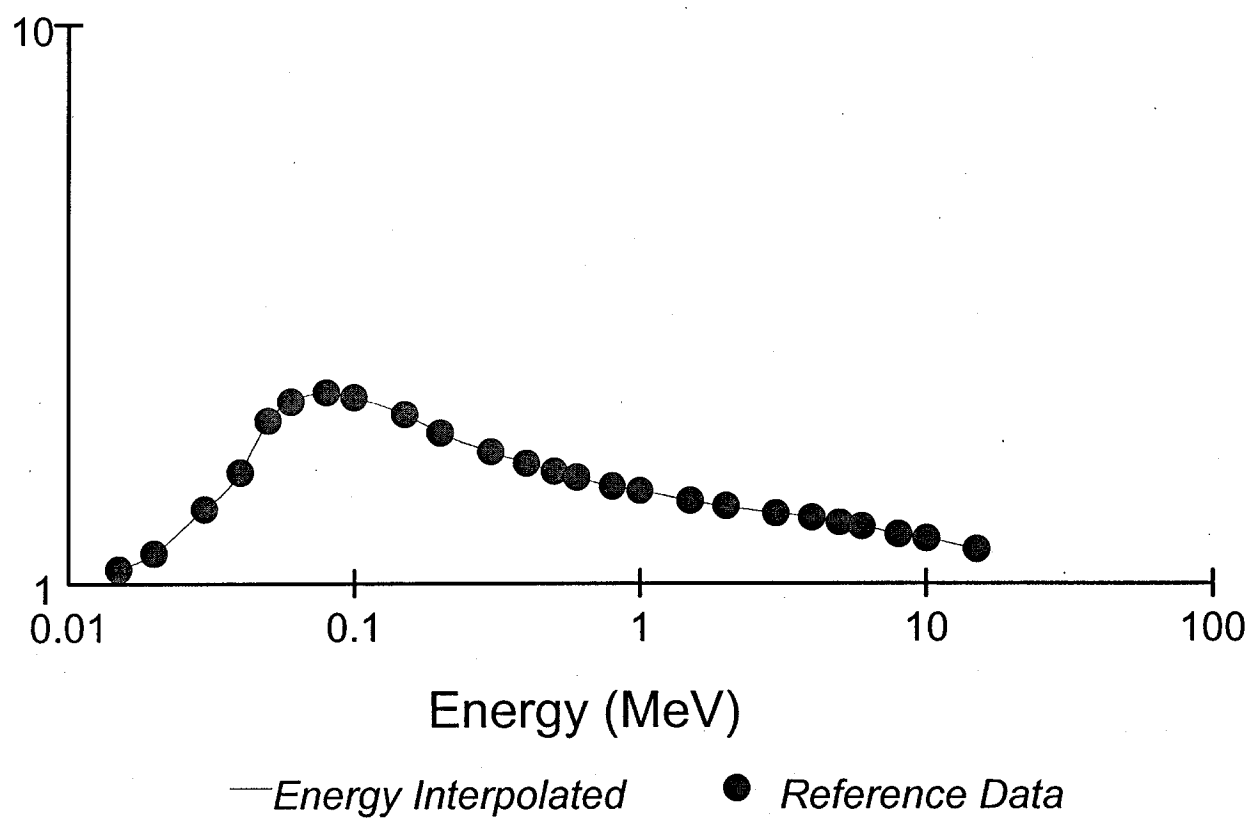
Silicon

0.23

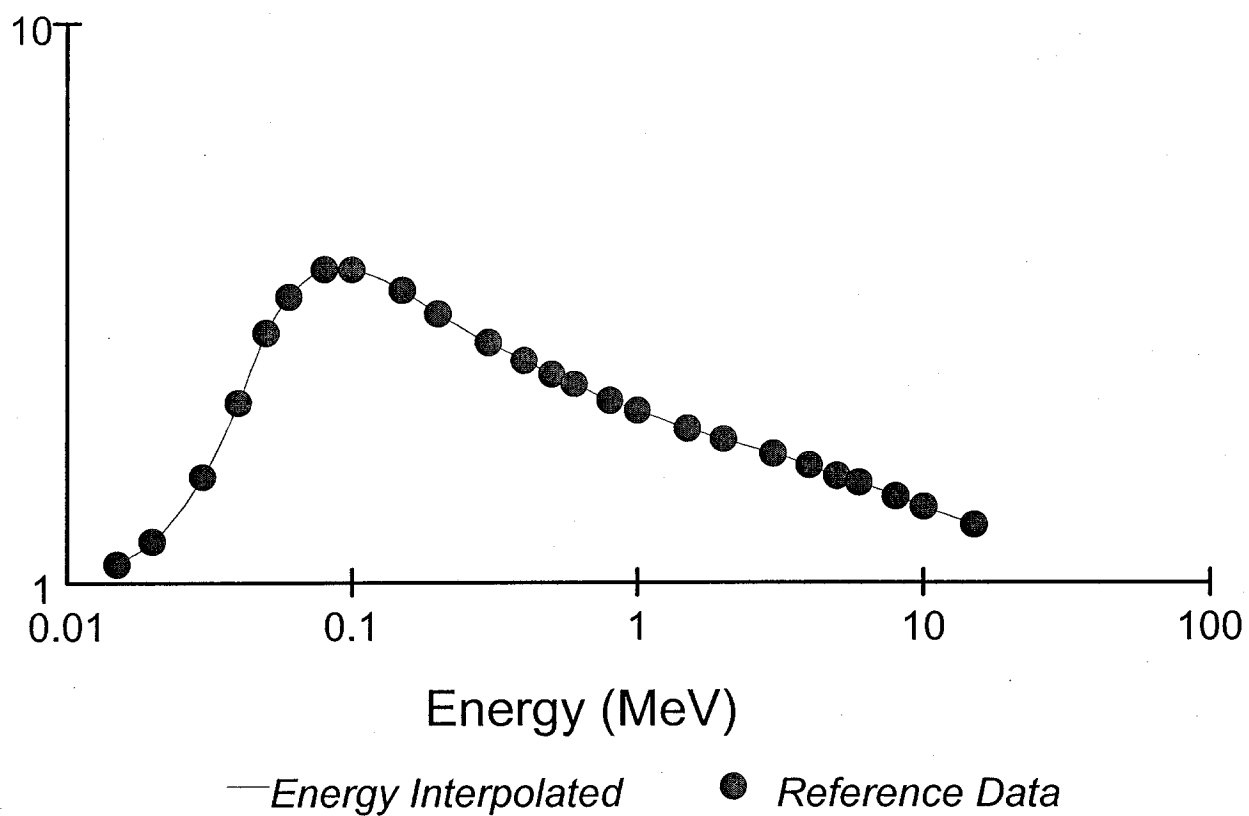
**ATTACHMENT 2**

**ATTENUATION PROPERTIES TABULATED BY MICROSHIELD™**

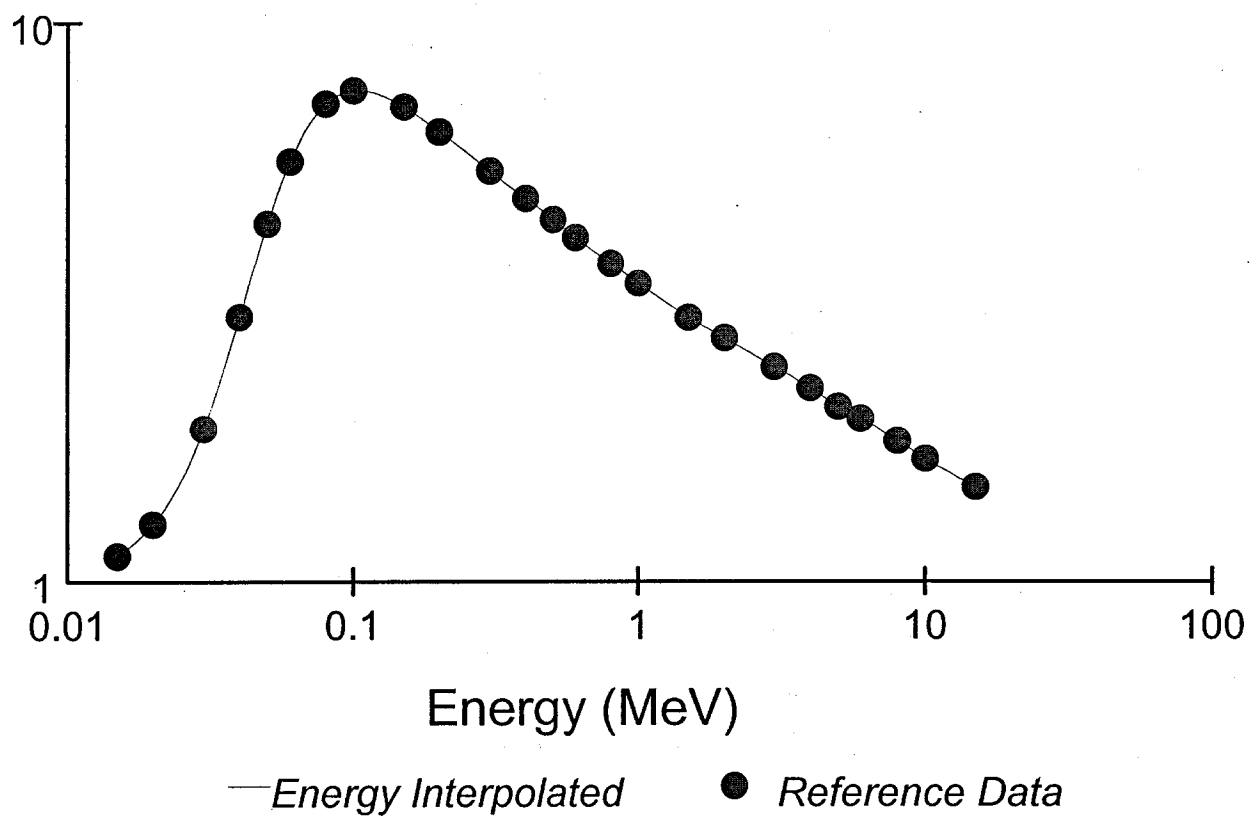
## Buildup Factors at 0.5 MFP for sandy loam moist



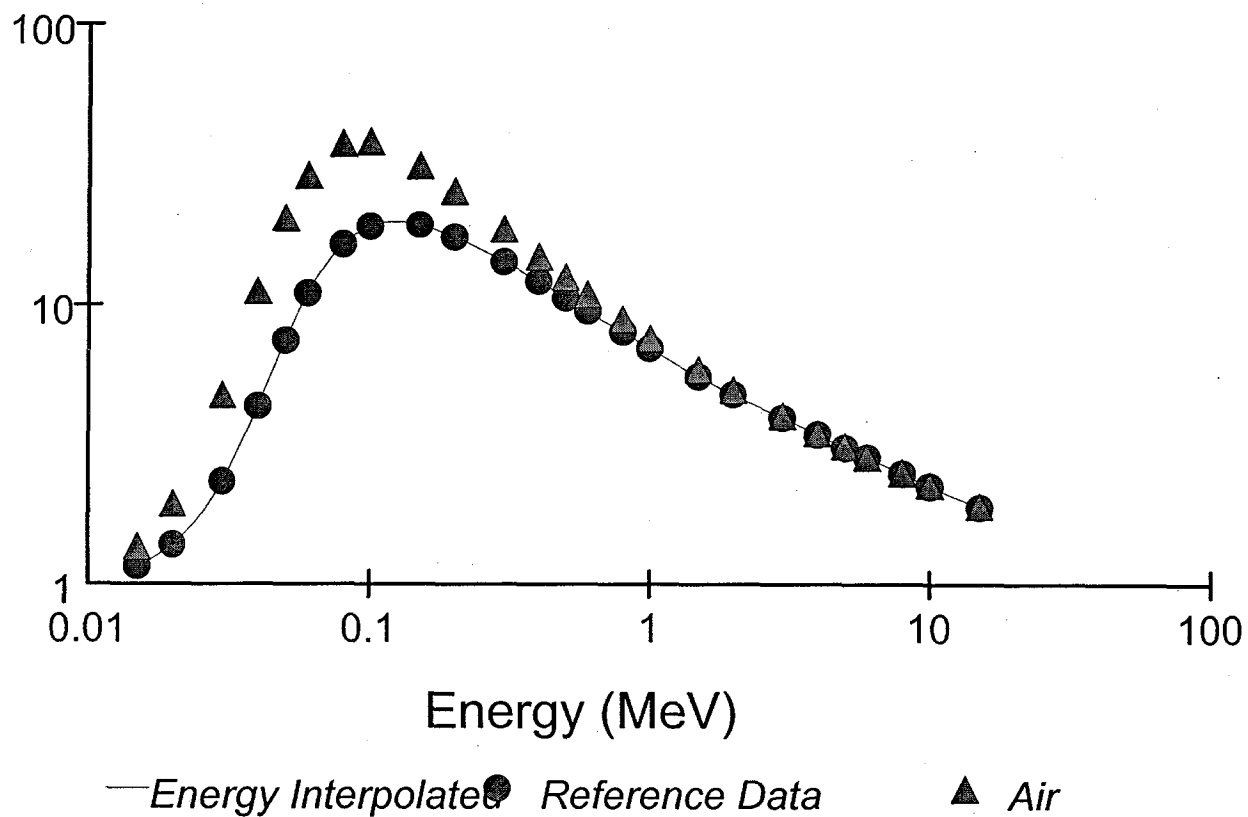
## Buildup Factors at 1.0 MFP for sandy loam moist



## Buildup Factors at 2.0 MFP for sandy loam moist

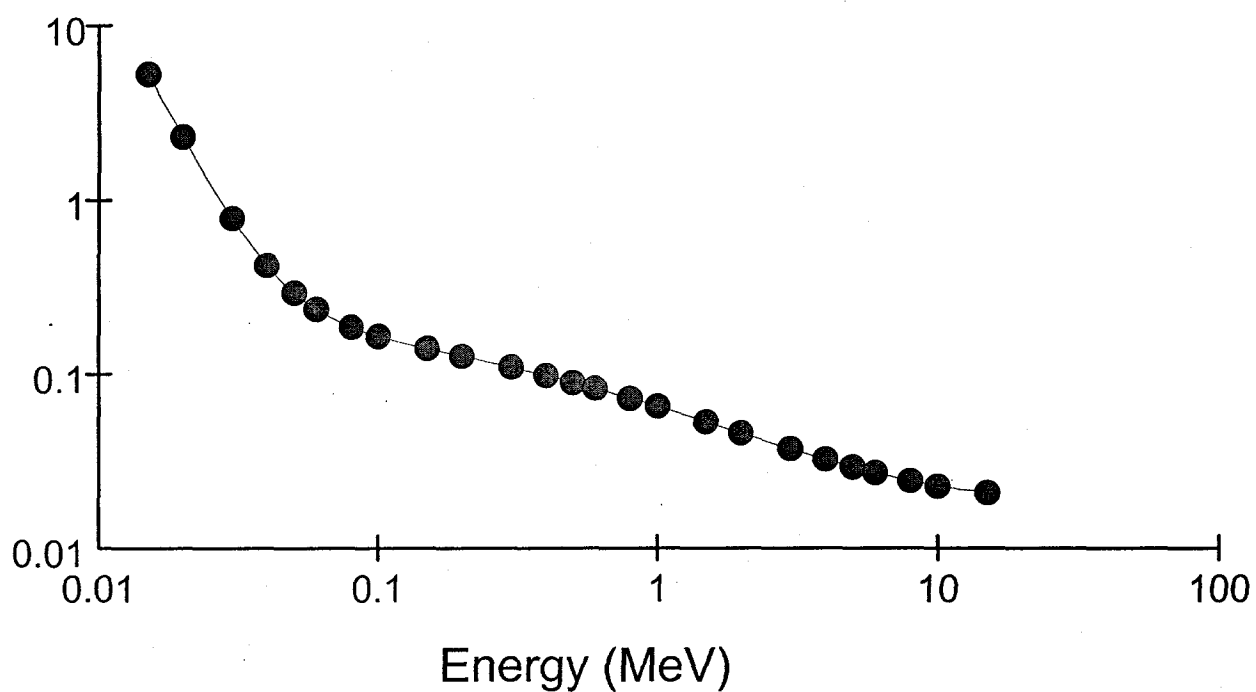


## Buildup Factors at 4.0 MFP for sandy loam moist





## Mass Attenuation Coefficients ( $\text{cm}^2/\text{g}$ ) for sandy loam moist



— Cubic Spline Interpolation

● Tabulated

## MicroShield v5.03 (5.03-00232)

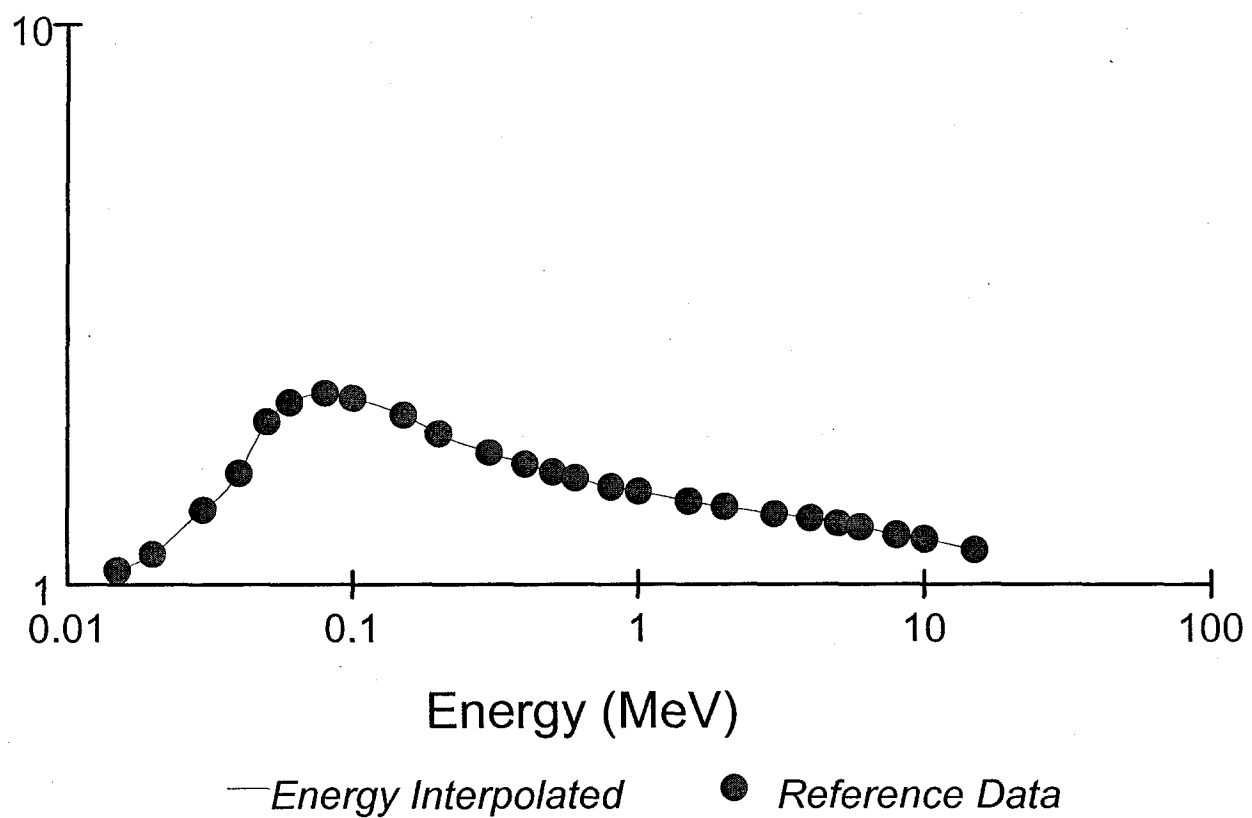
Tetra Tech EM Inc.

## Exposure Buildup Factors for sandy loam moist

Energy	0.5 MFP	1.0 MFP	2.0 MFP	3.0 MFP	4.0 MFP	5.0 MFP	6.0 MFP	7.0 MFP
0.015	1.059e+00	1.077e+00	1.111e+00	1.138e+00	1.156e+00	1.171e+00	1.178e+00	1.191e+00
0.02	1.131e+00	1.183e+00	1.265e+00	1.328e+00	1.378e+00	1.416e+00	1.450e+00	1.483e+00
0.03	1.355e+00	1.541e+00	1.875e+00	2.117e+00	2.323e+00	2.500e+00	2.664e+00	2.813e+00
0.04	1.578e+00	2.091e+00	2.975e+00	3.678e+00	4.321e+00	4.930e+00	5.510e+00	6.072e+00
0.05	1.953e+00	2.796e+00	4.357e+00	5.895e+00	7.450e+00	8.992e+00	1.055e+01	1.214e+01
0.06	2.115e+00	3.248e+00	5.639e+00	8.222e+00	1.099e+01	1.392e+01	1.702e+01	2.033e+01
0.08	2.196e+00	3.638e+00	7.153e+00	1.143e+01	1.643e+01	2.213e+01	2.865e+01	3.589e+01
0.10	2.151e+00	3.632e+00	7.550e+00	1.269e+01	1.912e+01	2.673e+01	3.578e+01	4.630e+01
0.15	2.005e+00	3.337e+00	7.058e+00	1.236e+01	1.932e+01	2.809e+01	3.893e+01	5.199e+01
0.20	1.857e+00	3.027e+00	6.367e+00	1.111e+01	1.746e+01	2.550e+01	3.551e+01	4.760e+01
0.30	1.718e+00	2.690e+00	5.421e+00	9.260e+00	1.426e+01	2.061e+01	2.831e+01	3.752e+01
0.40	1.638e+00	2.496e+00	4.838e+00	8.050e+00	1.213e+01	1.717e+01	2.321e+01	3.024e+01
0.50	1.586e+00	2.358e+00	4.434e+00	7.178e+00	1.060e+01	1.474e+01	1.959e+01	2.512e+01
0.60	1.546e+00	2.262e+00	4.119e+00	6.543e+00	9.490e+00	1.299e+01	1.707e+01	2.171e+01
0.80	1.490e+00	2.114e+00	3.700e+00	5.664e+00	7.972e+00	1.063e+01	1.359e+01	1.697e+01
1.00	1.463e+00	2.027e+00	3.414e+00	5.069e+00	6.972e+00	9.108e+00	1.148e+01	1.409e+01
1.50	1.403e+00	1.881e+00	2.969e+00	4.192e+00	5.525e+00	6.978e+00	8.517e+00	1.015e+01
2.00	1.373e+00	1.801e+00	2.728e+00	3.717e+00	4.770e+00	5.879e+00	7.034e+00	8.236e+00
3.00	1.333e+00	1.696e+00	2.424e+00	3.162e+00	3.928e+00	4.714e+00	5.517e+00	6.339e+00
4.00	1.310e+00	1.616e+00	2.221e+00	2.814e+00	3.424e+00	4.037e+00	4.664e+00	5.294e+00
5.00	1.283e+00	1.546e+00	2.058e+00	2.561e+00	3.068e+00	3.571e+00	4.086e+00	4.603e+00
6.00	1.263e+00	1.506e+00	1.956e+00	2.398e+00	2.836e+00	3.276e+00	3.720e+00	4.167e+00
8.00	1.223e+00	1.423e+00	1.786e+00	2.128e+00	2.476e+00	2.826e+00	3.180e+00	3.531e+00
10.00	1.200e+00	1.363e+00	1.658e+00	1.948e+00	2.236e+00	2.526e+00	2.820e+00	3.107e+00
15.00	1.150e+00	1.266e+00	1.476e+00	1.676e+00	1.878e+00	2.086e+00	2.293e+00	2.500e+00
Energy	8.0 MFP	10.0 MFP	15.0 MFP	20.0 MFP	25.0 MFP	30.0 MFP	35.0 MFP	40.0 MFP
0.015	1.206e+00	1.220e+00	1.255e+00	1.274e+00	1.293e+00	1.310e+00	1.324e+00	1.337e+00
0.02	1.505e+00	1.556e+00	1.659e+00	1.725e+00	1.792e+00	1.839e+00	1.880e+00	1.914e+00
0.03	2.957e+00	3.210e+00	3.781e+00	4.263e+00	4.706e+00	5.107e+00	5.460e+00	5.732e+00
0.04	6.605e+00	7.661e+00	1.020e+01	1.265e+01	1.503e+01	1.735e+01	1.957e+01	2.168e+01
0.05	1.375e+01	1.714e+01	2.613e+01	3.600e+01	4.700e+01	5.891e+01	7.161e+01	8.487e+01
0.06	2.377e+01	3.141e+01	5.405e+01	8.233e+01	1.160e+02	1.554e+02	2.013e+02	2.566e+02
0.08	4.396e+01	6.267e+01	1.261e+02	2.169e+02	3.394e+02	4.993e+02	6.984e+02	9.427e+02
0.10	5.845e+01	8.789e+01	1.979e+02	3.721e+02	6.287e+02	9.864e+02	1.467e+03	2.091e+03
0.15	6.737e+01	1.068e+02	2.660e+02	5.427e+02	9.814e+02	1.628e+03	2.547e+03	3.807e+03
0.20	6.188e+01	9.850e+01	2.471e+02	5.054e+02	9.112e+02	1.506e+03	2.332e+03	3.432e+03
0.30	4.841e+01	7.548e+01	1.816e+02	3.557e+02	6.153e+02	9.721e+02	1.443e+03	2.018e+03
0.40	3.851e+01	5.845e+01	1.320e+02	2.456e+02	4.024e+02	6.092e+02	8.687e+02	1.184e+03
0.50	3.152e+01	4.671e+01	9.998e+01	1.762e+02	2.770e+02	4.031e+02	5.555e+02	7.328e+02

<u>Energy</u>	<u>8.0 MFP</u>	<u>10.0 MFP</u>	<u>15.0 MFP</u>	<u>20.0 MFP</u>	<u>25.0 MFP</u>	<u>30.0 MFP</u>	<u>35.0 MFP</u>	<u>40.0 MFP</u>
0.80	2.689e+01	3.912e+01	8.051e+01	1.375e+02	2.111e+02	3.000e+02	4.046e+02	5.258e+02
1.00	2.066e+01	2.901e+01	5.541e+01	8.922e+01	1.301e+02	1.770e+02	2.304e+02	2.890e+02
1.50	1.690e+01	2.306e+01	4.182e+01	6.458e+01	9.091e+01	1.201e+02	1.532e+02	1.878e+02
2.00	1.187e+01	1.556e+01	2.580e+01	3.738e+01	5.008e+01	6.361e+01	7.799e+01	9.298e+01
3.00	9.474e+00	1.202e+01	1.899e+01	2.648e+01	3.430e+01	4.259e+01	5.106e+01	5.971e+01
4.00	7.179e+00	8.892e+00	1.333e+01	1.800e+01	2.284e+01	2.779e+01	3.280e+01	3.781e+01
5.00	5.938e+00	7.227e+00	1.054e+01	1.391e+01	1.733e+01	2.084e+01	2.435e+01	2.791e+01
6.00	5.120e+00	6.159e+00	8.796e+00	1.149e+01	1.413e+01	1.677e+01	1.923e+01	2.151e+01
8.00	4.619e+00	5.514e+00	7.797e+00	1.013e+01	1.244e+01	1.472e+01	1.722e+01	1.998e+01
10.00	3.879e+00	4.589e+00	6.364e+00	8.157e+00	9.952e+00	1.175e+01	1.366e+01	1.553e+01
15.00	3.399e+00	3.987e+00	5.482e+00	6.992e+00	8.536e+00	1.007e+01	1.165e+01	1.337e+01
	2.714e+00	3.143e+00	4.248e+00	5.393e+00	6.570e+00	7.767e+00	8.932e+00	9.997e+00

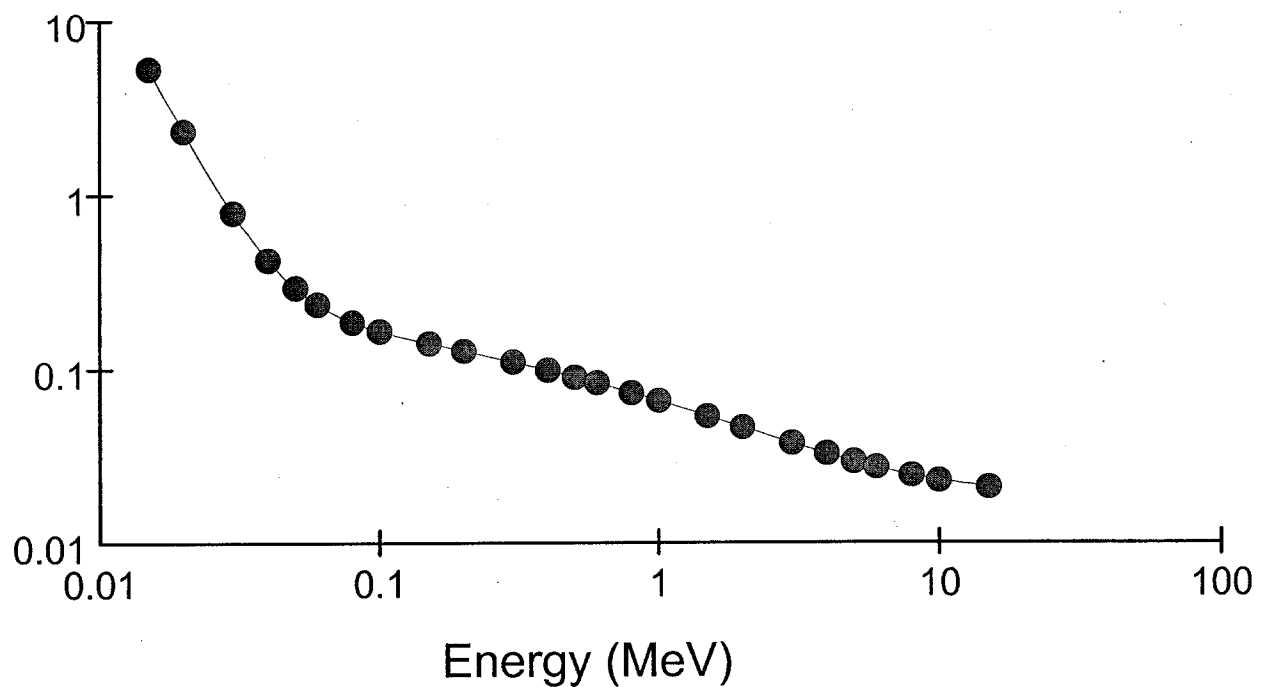
## Buildup Factors at 0.5 MFP for sandy loam moist



**MicroShield v5.03 (5.03-00232)**  
**Tetra Tech EM Inc.**  
**Attenuation Coefficients for sandy loam moist**  
**(without coherent scattering)**  
**Density: 1.25000 g/cm<sup>3</sup>**

Energy (MeV)	Mass Atten Coeff (cm <sup>2</sup> /gm)	Linear Atten Coeff (1/cm)	Half Thickness (cm)
0.015	5.27554	6.594431	.105
0.020	2.30259	2.878232	.241
0.030	.78502	.981272	.706
0.040	.42165	.527065	1.315
0.050	.29300	.366253	1.893
0.060	.23531	.294140	2.357
0.080	.18615	.232685	2.979
0.100	.16489	.206114	3.363
0.150	.14027	.175331	3.953
0.200	.12668	.158349	4.377
0.300	.10939	.136740	5.069
0.400	.09777	.122208	5.672
0.500	.08920	.111499	6.217
0.600	.08249	.103116	6.722
.800	.07244	.090554	7.655
1.000	.06512	.081398	8.516
1.500	.05302	.066281	10.458
2.000	.04565	.057065	12.147
3.000	.03703	.046290	14.974
4.000	.03214	.040177	17.253
5.000	.02899	.036242	19.125
6.000	.02684	.033555	20.657
8.000	.02414	.030169	22.975
10.000	.02256	.028194	24.585
15.000	.02063	.025793	26.873

## Mass Attenuation Coefficients ( $\text{cm}^2/\text{g}$ ) for sandy loam moist



— Cubic Spline Interpolation

● Tabulated

**ATTACHMENT 3**  
**SOURCE ACTIVITY FILE**

## MicroShield v5.03 (5.03-00232)

Tetra Tech EM Inc.

External Source File: 5SOIL.MX5

Title: 5 pci/gram ra-226 equilibrium - 29% moisture

<u>Nuclide</u>	<u><math>\mu\text{Ci}/\text{cm}^3</math></u>	<u><math>\text{Bq}/\text{cm}^3</math></u>
Bi-210	4.2500e-006	1.5725e-001
Bi-214	4.2500e-006	1.5725e-001
Pb-210	4.2500e-006	1.5725e-001
Pb-214	4.2500e-006	1.5725e-001
Po-210	4.2500e-006	1.5725e-001
Po-214	4.2500e-006	1.5725e-001
Po-218	4.2500e-006	1.5725e-001
Ra-226	4.2500e-006	1.5725e-001
Rn-222	4.2500e-006	1.5725e-001



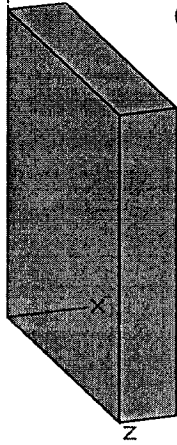
**ATTACHMENT 4**  
**MICROSHIELD™ OUTPUTS**

Page : 1  
 File : S-PILE-6.MS5  
 Date: April 7, 1999  
 Run Time: 11:58:01 AM  
 Duration : 00:00:10

File Ref: \_\_\_\_\_  
 Date: \_\_\_\_\_  
 By: \_\_\_\_\_  
 Checked: \_\_\_\_\_

**Case Title: Sheet Pile Shield**

**Description: std source with no cover soil layer and 0 cm steel 10 cm spa**  
**Geometry: 13 - Rectangular Volume**

**Source Dimensions**

Length	15.0 cm	5.9 in
Width	80.0 cm	2 ft 7.5 in
Height	80.0 cm	2 ft 7.5 in

**Dose Points**

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	20 cm 7.9 in	40 cm 1 ft 3.7 in	40 cm 1 ft 3.7 in

**Shields**

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	9.60e+04 cm <sup>3</sup>	sandy loam moist	1.25
Air Gap		Air	0.00122

**Source Input****Grouping Method : Standard Indices****Number of Groups : 25****Lower Energy Cutoff : 0.015****Photons < 0.015 : Excluded****Library : Grove**

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm<sup>3</sup></u>	<u>Bq/cm<sup>3</sup></u>
Bi-210	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Bi-214	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Pb-210	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Pb-214	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Po-210	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Po-214	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Po-218	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Ra-226	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Rn-222	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001

**Buildup****The material reference is : Source****Integration Parameters**

X Direction

10

Page : 2  
 DOS File : S-PILE-6.MS5  
 Run Date: April 7, 1999  
 Run Time: 11:58:01 AM  
 Duration : 00:00:10

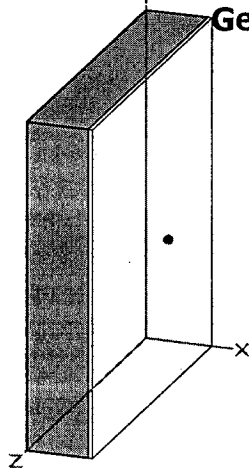
Y Direction 20  
 Z Direction 20

### Results

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm<sup>2</sup>/sec</u>		<u>Exposure Rate</u> <u>mR/hr</u>	
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.05	7.783e+02	4.854e-04	1.305e-03	1.293e-06	3.477e-06
0.08	3.480e+03	5.401e-03	2.060e-02	8.548e-06	3.261e-05
0.1	2.049e+01	4.457e-05	1.737e-04	6.819e-08	2.657e-07
0.2	1.626e+03	8.994e-03	2.825e-02	1.587e-05	4.985e-05
0.3	3.115e+03	2.933e-02	7.753e-02	5.565e-05	1.471e-04
0.4	5.777e+03	7.958e-02	1.869e-01	1.551e-04	3.641e-04
0.5	2.697e+02	4.994e-03	1.073e-02	9.803e-06	2.107e-05
0.6	7.279e+03	1.717e-01	3.445e-01	3.352e-04	6.725e-04
0.8	1.427e+03	4.934e-02	8.934e-02	9.384e-05	1.699e-04
1.0	4.727e+03	2.198e-01	3.717e-01	4.052e-04	6.852e-04
1.5	2.874e+03	2.281e-01	3.440e-01	3.837e-04	5.787e-04
2.0	4.040e+03	4.649e-01	6.572e-01	7.190e-04	1.016e-03
TOTALS:	3.541e+04	1.263e+00	2.132e+00	2.183e-03	3.741e-03

Page : 1  
 DOC File : S-PILE-7.MS5  
 Rate: April 7, 1999  
 Run Time: 11:58:42 AM  
 Duration : 00:00:10

File Ref: \_\_\_\_\_  
 Date: \_\_\_\_\_  
 By: \_\_\_\_\_  
 Checked: \_\_\_\_\_

**Case Title: Sheet Pile Shield****Description: std source with no cover soil layer and 1 cm steel 10 cm spa****Geometry: 13 - Rectangular Volume****Source Dimensions**

Length	15.0 cm	5.9 in
Width	80.0 cm	2 ft 7.5 in
Height	80.0 cm	2 ft 7.5 in

**Dose Points**

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	20 cm 7.9 in	40 cm 1 ft 3.7 in	40 cm 1 ft 3.7 in

**Shields**

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	9.60e+04 cm <sup>3</sup>	sandy loam moist	1.25
Shield 1	1.0 cm	Iron	7.8
Air Gap		Air	0.00122

**Source Input****Grouping Method : Standard Indices****Number of Groups : 25****Lower Energy Cutoff : 0.015****Photons < 0.015 : Excluded****Library : Grove**

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm<sup>3</sup></u>	<u>Bq/cm<sup>3</sup></u>
Bi-210	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Bi-214	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Pb-210	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Pb-214	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Po-210	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Po-214	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Po-218	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Ra-226	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001
Rn-222	4.0800e-007	1.5096e+004	4.2500e-006	1.5725e-001

**Buildup****The material reference is : Source****Integration Parameters**

Page : 2  
 DOS File : S-PILE-7.MS5  
 Run Date: April 7, 1999  
 Run Time: 11:58:42 AM  
 Duration : 00:00:10

X Direction	10
Y Direction	20
Z Direction	20

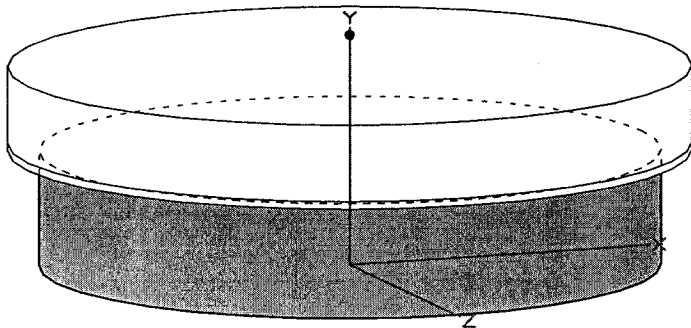
# Results

<u>Energy</u>	<u>Activity</u>	<u>Fluence Rate</u>	<u>Fluence Rate</u>	<u>Exposure Rate</u>	<u>Exposure Rate</u>
<u>MeV</u>	<u>photons/sec</u>	<u>MeV/cm<sup>2</sup>/sec</u>	<u>MeV/cm<sup>2</sup>/sec</u>	<u>mR/hr</u>	<u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.05	7.783e+02	1.737e-11	5.005e-10	4.628e-14	1.333e-12
0.08	3.480e+03	1.377e-05	3.982e-04	2.179e-08	6.301e-07
0.1	2.049e+01	8.048e-07	1.742e-05	1.231e-09	2.665e-08
0.2	1.626e+03	1.348e-03	1.215e-02	2.379e-06	2.144e-05
0.3	3.115e+03	6.374e-03	3.988e-02	1.209e-05	7.565e-05
0.4	5.777e+03	2.059e-02	1.028e-01	4.012e-05	2.004e-04
0.5	2.697e+02	1.449e-03	6.139e-03	2.844e-06	1.205e-05
0.6	7.279e+03	5.425e-02	2.025e-01	1.059e-04	3.952e-04
0.8	1.427e+03	1.767e-02	5.470e-02	3.362e-05	1.040e-04
1.0	4.727e+03	8.633e-02	2.343e-01	1.591e-04	4.318e-04
1.5	2.874e+03	1.042e-01	2.288e-01	1.753e-04	3.850e-04
2.0	4.040e+03	2.319e-01	4.522e-01	3.586e-04	6.993e-04
ALS:	3.541e+04	5.242e-01	1.334e+00	8.901e-04	2.326e-03

Page : 1  
 Doc File : ASPH-1.MS5  
 Run Date: April 7, 1999  
 Run Time: 2:23:22 PM  
 Duration : 00:00:01

File Ref: \_\_\_\_\_  
 Date: \_\_\_\_\_  
 By: \_\_\_\_\_  
 Checked: \_\_\_\_\_

**Case Title: soil shield test cas**  
**Description: asphalt layer and soil layer**  
**Geometry: 8 - Cylinder Volume - End Shields**

**Source Dimensions**

Height	15.0 cm	5.9 in
Radius	40.0 cm	1 ft 3.7 in

**Dose Points**

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	0 cm 0.0 in	30 cm 11.8 in	0 cm 0.0 in

**Shields**

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	7.54e+04 cm <sup>3</sup>	sandy loam moist	1.25
Shield 1	1.0 cm	sandy loam moist	1.25
Shield 2	10.0 cm	asphalt	1.25
Air Gap		Air	0.00122

**Source Input****Grouping Method : Standard Indices****Number of Groups : 25****Lower Energy Cutoff : 0.015****Photons < 0.015 : Excluded****Library : Grove**

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm<sup>3</sup></u>	<u>Bq/cm<sup>3</sup></u>
Bi-210	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Bi-214	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Pb-210	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Pb-214	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Po-210	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Po-214	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Po-218	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Ra-226	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001
Rn-222	3.2044e-007	1.1856e+004	4.2500e-006	1.5725e-001

**Buildup****The material reference is : Shield 2****Integration Parameters**

Page : 2  
 DOS File : ASPH-1.MS5  
 Run Date: April 7, 1999  
 Run Time: 2:23:22 PM  
 Duration : 00:00:01

Radial	20
Circumferential	10
Y Direction (axial)	10

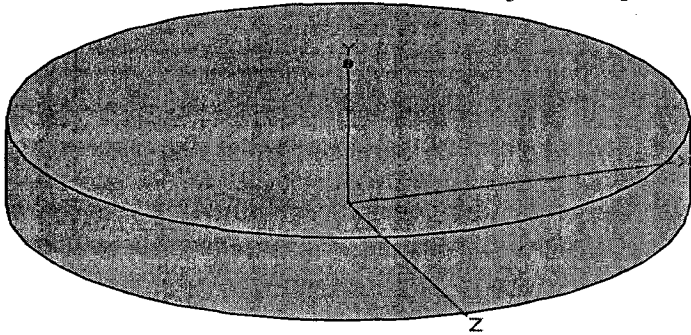
### Results

<u>Energy</u> <u>MeV</u>	<u>Activity</u> <u>photons/sec</u>	<u>Fluence Rate</u> <u>MeV/cm<sup>2</sup>/sec</u>	<u>Fluence Rate</u> <u>MeV/cm<sup>2</sup>/sec</u>	<u>Exposure Rate</u> <u>mR/hr</u>	<u>Exposure Rate</u> <u>mR/hr</u>
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.05	6.112e+02	9.077e-06	6.400e-04	2.418e-08	1.705e-06
0.08	2.733e+03	1.722e-04	1.414e-02	2.726e-07	2.237e-05
0.1	1.609e+01	1.686e-06	1.130e-04	2.580e-09	1.729e-07
0.2	1.277e+03	5.572e-04	1.378e-02	9.834e-07	2.432e-05
0.3	2.447e+03	2.418e-03	3.285e-02	4.586e-06	6.231e-05
0.4	4.537e+03	7.986e-03	7.489e-02	1.556e-05	1.459e-04
0.5	2.118e+02	5.809e-04	4.131e-03	1.140e-06	8.110e-06
0.6	5.717e+03	2.245e-02	1.304e-01	4.381e-05	2.545e-04
0.8	1.120e+03	7.676e-03	3.339e-02	1.460e-05	6.350e-05
1.0	3.712e+03	3.886e-02	1.381e-01	7.164e-05	2.545e-04
1.5	2.257e+03	4.975e-02	1.308e-01	8.371e-05	2.200e-04
2.0	3.173e+03	1.154e-01	2.551e-01	1.784e-04	3.945e-04
ALS:	2.781e+04	2.459e-01	8.283e-01	4.148e-04	1.452e-03

Page : 1  
 Doc File : MARSIM.MS5  
 Run Date: April 15, 1999  
 Run Time: 4:04:37 PM  
 Duration : 00:00:01

File Ref: \_\_\_\_\_  
 Date: \_\_\_\_\_  
 By: \_\_\_\_\_  
 Checked: \_\_\_\_\_

**Case Title: Default MARSSIM**  
**Description: Marssim example case**  
**Geometry: 8 - Cylinder Volume - End Shields**

**Source Dimensions**

Height	15.0 cm	5.9 in
Radius	58.0 cm	1 ft 10.8 in

**Dose Points**

	<u>X</u>	<u>Y</u>	<u>Z</u>
# 1	0 cm 0.0 in	25 cm 9.8 in	0 cm 0.0 in

**Shields**

<u>Shield Name</u>	<u>Dimension</u>	<u>Material</u>	<u>Density</u>
Source	1.59e+05 cm <sup>3</sup>	sandy loam moist	1.25
Air Gap		Air	0.00122

**Source Input****Grouping Method : Standard Indices****Number of Groups : 25****Lower Energy Cutoff : 0.015****Photons < 0.015 : Excluded****Library : Grove**

<u>Nuclide</u>	<u>curies</u>	<u>becquerels</u>	<u>μCi/cm<sup>3</sup></u>	<u>Bq/cm<sup>3</sup></u>
Bi-210	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Bi-214	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Pb-210	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Pb-214	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Po-210	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Po-214	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Po-218	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Ra-226	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001
Rn-222	6.7373e-007	2.4928e+004	4.2500e-006	1.5725e-001

**Buildup****The material reference is : Air Gap****Integration Parameters**

Radial	20
Circumferential	10



Page : 2  
DOS File : MARSIM.MS5  
Run Date: April 15, 1999  
Run Time: 4:04:37 PM  
Duration : 00:00:01

Y Direction (axial)

10

**Results**

<u>Energy</u> MeV	<u>Activity</u> photons/sec	<u>Fluence Rate</u> MeV/cm <sup>2</sup> /sec		<u>Exposure Rate</u> mR/hr	
		<u>No Buildup</u>	<u>With Buildup</u>	<u>No Buildup</u>	<u>With Buildup</u>
0.05	1.285e+03	4.537e-04	2.132e-03	1.209e-06	5.679e-06
0.08	5.747e+03	5.038e-03	3.015e-02	7.973e-06	4.771e-05
0.1	3.383e+01	4.155e-05	2.308e-04	6.357e-08	3.530e-07
0.2	2.685e+03	8.376e-03	3.042e-02	1.478e-05	5.370e-05
0.3	5.144e+03	2.730e-02	7.861e-02	5.179e-05	1.491e-04
0.4	9.539e+03	7.404e-02	1.841e-01	1.443e-04	3.587e-04
0.5	4.453e+02	4.646e-03	1.043e-02	9.119e-06	2.048e-05
0.6	1.202e+04	1.597e-01	3.321e-01	3.117e-04	6.482e-04
0.8	2.356e+03	4.587e-02	8.519e-02	8.725e-05	1.620e-04
1.0	7.805e+03	2.043e-01	3.526e-01	3.767e-04	6.500e-04
1.5	4.746e+03	2.120e-01	3.246e-01	3.566e-04	5.462e-04
2.0	6.671e+03	4.321e-01	6.165e-01	6.682e-04	9.533e-04
TOTALS:	5.848e+04	1.174e+00	2.047e+00	2.030e-03	3.595e-03